Fundamentals of Catastrophe Modeling

Presented to the Coastal Hazards Commission

Karen M. Clark
President & CEO
AIR Worldwide Corporation

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www.air-worldwide.com

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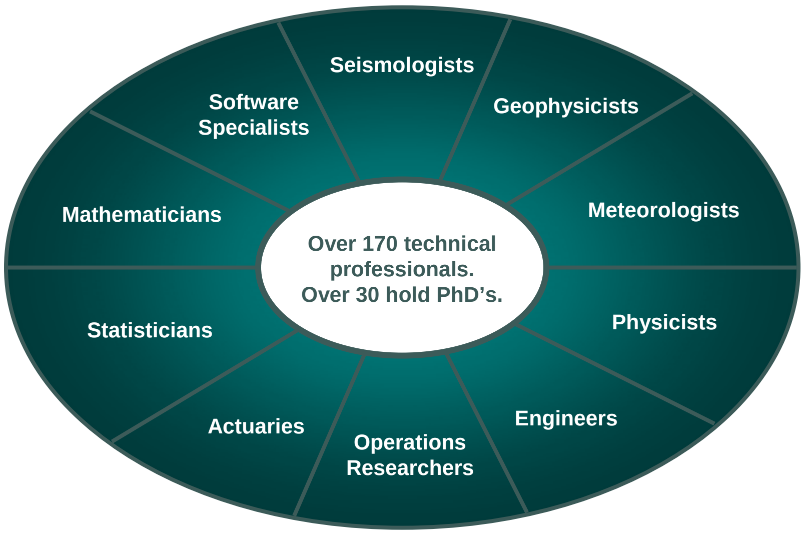
AIR

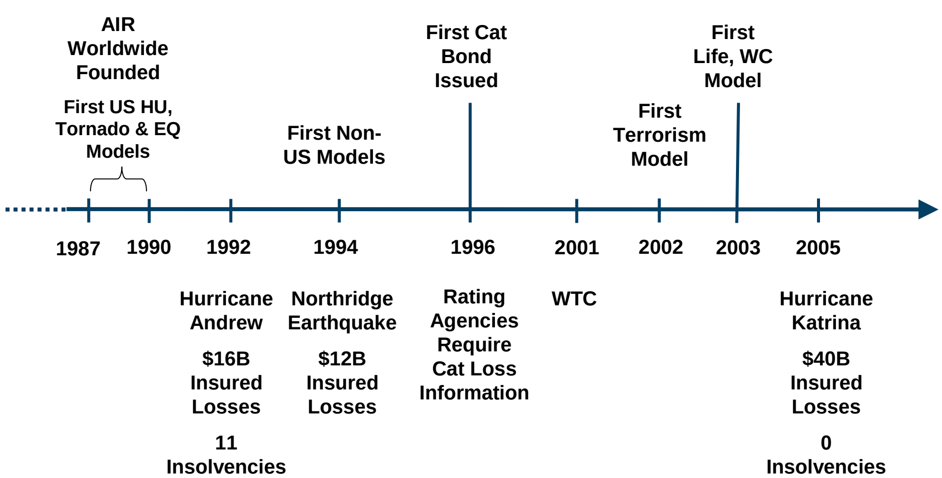
About AIR

- AIR Worldwide was founded in 1987 as the first catastrophe modeling company
- Pioneered the development and application of probabilistic catastrophe loss estimation methodology that is now the standard technology for global risk assessment and management
- AIR models and software systems cover natural hazards in more than 50 countries, as well as terrorism in the U.S.
- Advanced scientific techniques help clients assess and manage catastrophe, weather and climate risk
  - Over 400 insurer, reinsurer, intermediary, and corporate risk manager clients
  - Research-oriented clients include Earthquake Engineering Research Institute, Pacific Earthquake Engineering Research Center, Los Alamos National Labs
  - Government clients include USDA, USGS, US Dept. of Homeland Security
- Offices in Boston, San Francisco, London, Hyderabad, Munich and Beijing

AIR Technical Staff



History of Catastrophe Modeling

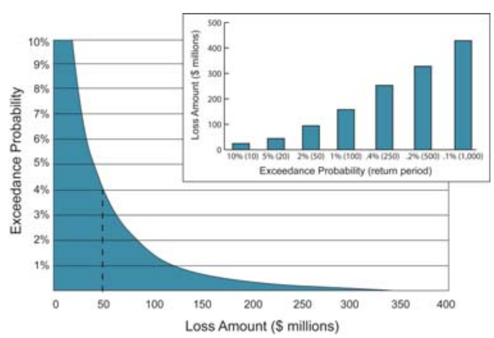


How Insurance Companies Utilize Catastrophe Model Output

- Risk assessment and transfer
  - Estimating complete probability distributions of loss, including large loss potential
  - Analyzing additional risk transfer options, such as catastrophe bonds, etc.
  - Analyzing various reinsurance options
- Underwriting enhancement
  - Estimating losses down to the individual policy level for risk selection
  - Evaluating the impact of changing policy conditions, such as deductibles
  - Developing underwriting guidelines that account for catastrophe risk
- Pricing adequacy
  - Performing ratemaking analyses to develop loss costs in risk-prone areas
  - Evaluating impacts of various mitigation devices for the development of appropriate credits
- Portfolio management
  - Developing portfolio growth strategies to determine allocation and reserving of capital
  - Performing optimization studies to identify policies that contribute the most to portfolio PML

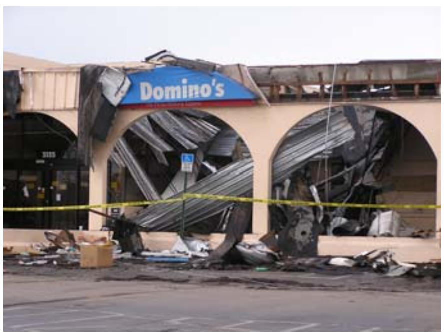
AIR Catastrophe Modeling Approach

- AIR catastrophe loss estimation methodology uses statistical and physical simulations to generate a large enough sample of potential future loss experience
- Fundamental physical characteristics of catastrophe events expressed mathematically
- Superimposed on current building stock
- Model results are expressed as a distribution of probabilities, or the likelihood of various levels of loss



What Questions are Catastrophe Models Designed to Answer?

- Where are future events likely to occur?
- How big are they likely to be? How frequently are they likely to occur?
- For each potential event, what will be the property damage and insured losses? What will be the number of people injured?



AIR Hurricane Model for the U.S.

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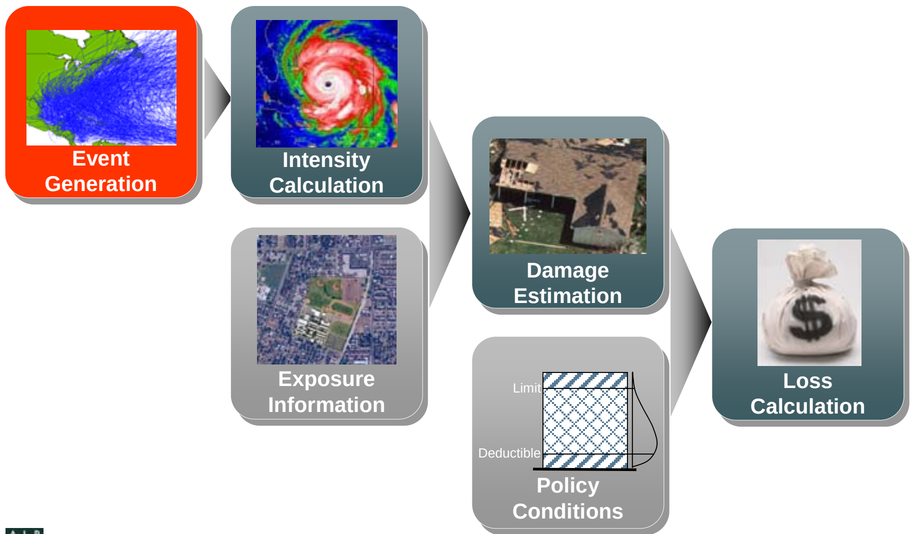
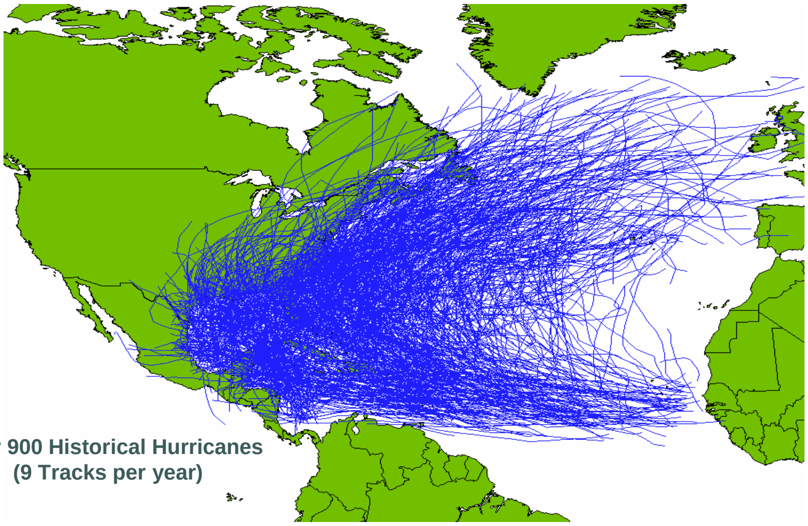
Catastrophe Modeling Framework



Event Generation

- Thousands of ‘scenario years’ are simulated to produce a large stochastic storm catalog of landfalling and bypassing events for full spatial coverage and stable results
- For each scenario year, the model generates the number of hurricanes that occur that year
- For each simulated hurricane, parameter values are assigned probabilistically
  - Landfall location
  - Minimum central pressure
  - Radius of maximum winds
  - Forward speed
  - Track angle at landfall
  - Track direction at each time step

North Atlantic Tropical Cyclones Since 1900



Over 900 Historical Hurricanes
(9 Tracks per year)

Historical Data on Hurricanes

Wind Speed and Central Pressure Along Storm Track

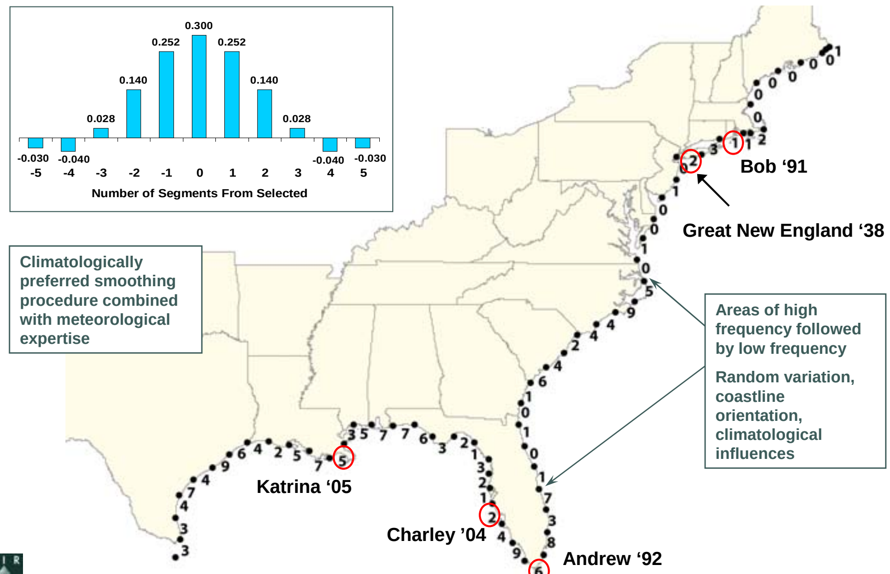
Date/Time (UTC)	Position Lat.(°N)	Position Lon.(°W)	Pressure (mb)	Wind Speed (kt)	Stage
16/1800	10.8	35.5	1010	25	Tropical Depression
17/0000	11.2	37.4	1009	30	" "
0600	11.7	39.6	1008	30	" "
1200	12.3	42.0	1006	35	Tropical Storm
1800	13.1	44.2	1003	35	" "
18/0000	13.6	46.2	1002	40	" "
0600	14.1	48.0	1001	45	" "
1200	14.6	49.9	1000	45	" "
1800	15.4	51.8	1000	45	" "
19/0000	16.3	53.5	1001	45	" "
0600	17.2	55.3	1002	45	" "
1200	18.0	56.9	1005	45	" "
1800	18.8	58.3	1007	45	" "
20/0000	19.8	59.3	1011	40	" "
0600	20.7	60.0	1013	40	" "
1200	21.7	60.7	1015	40	" "
1800	22.5	61.5	1014	40	" "
21/0000	23.2	62.4	1014	45	" "
0600	23.9	63.3	1010	45	" "
1200	24.4	64.2	1007	50	" "
1800	24.8	64.9	1004	50	" "
22/0000	25.3	65.9	1000	55	" "
0600	25.6	67.0	994	60	" "
1200	25.8	68.3	981	70	Hurricane

Detailed Landfall Characteristics

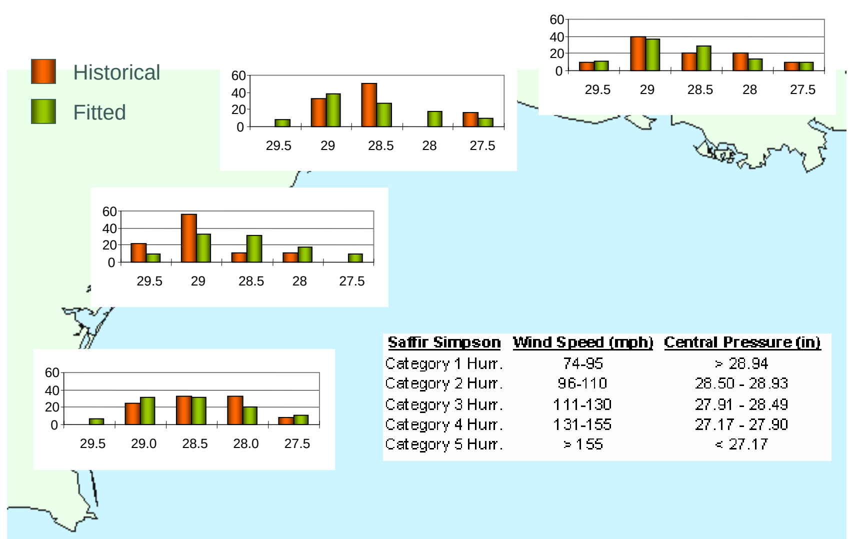
Hurricane	Date	Central Pressure (in)	Central Pressure (kPa)	RMax n.mi.	RMax km	Forward Speed kt	Forward Speed km/hr	Max Wind Speed kt	Max Wind Speed Km/hr
Galveston	9/9/00	27.64	93.6	14	26	10	18	77	143
Central Gulf	9/13/19	27.99	94.8	32	39	10	18	91	167
New England	9/21/38	27.76	94.0	50	93	40	24	85	158
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
Helene	9/27/58	27.52	93.2	20	32	14	26	93	176
Donna	9/11/60	28.67	97.1	34	63	20	37	85	158
Carla	9/10/61	27.61	93.5	20	37.1	8	15	104	193

Sources: National Oceanic and Atmospheric Administration, National Hurricane Center, US Army Corps of Engineers, National Weather Service, National Climatic Data Center

Hurricane Landfalls by Location

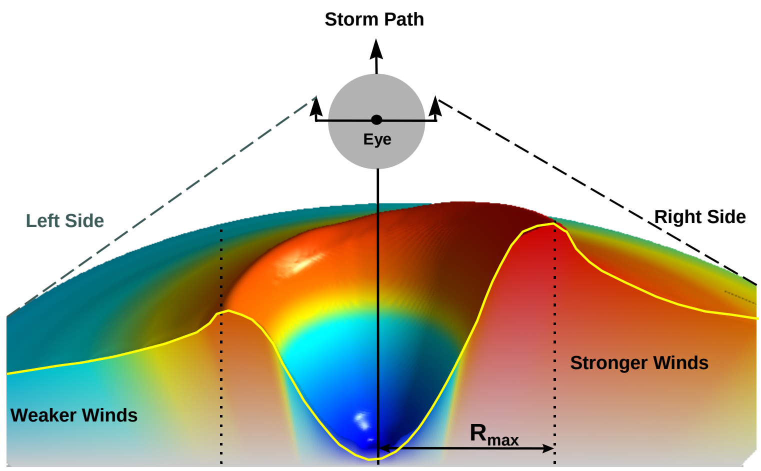


Estimating Storm Intensity by Landfall Location

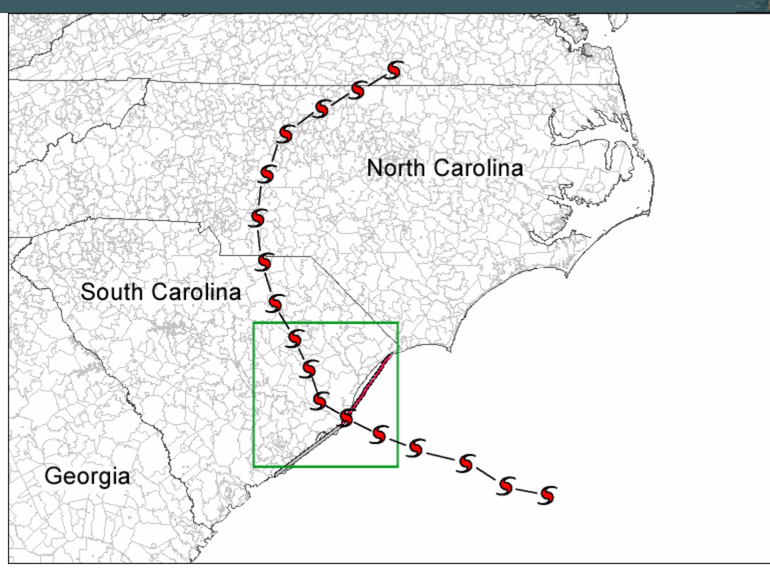


Saffir Simpson	Wind Speed (mph)	Central Pressure (in)
Category 1 Hurr.	74-95	> 28.94
Category 2 Hurr.	96-110	28.50 - 28.93
Category 3 Hurr.	111-130	27.91 - 28.49
Category 4 Hurr.	131-155	27.17 - 27.90
Category 5 Hurr.	> 155	< 27.17

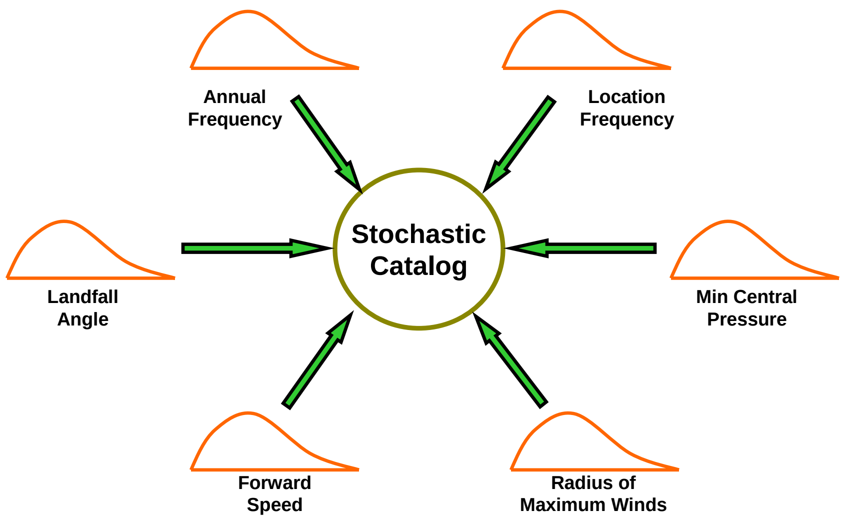
Radius of Maximum Winds (Rmax) Key Driver of Storm Size



Storm Track Generation Procedure — Mainland U.S.



Stochastic Catalog Generated from Distributions of Important Storm Characteristics



Stochastic Hurricane Catalog

- AIR's hurricane catalog contains storm parameters for each event in a given year
- Catalog methodology facilitates straight-forward modeling of multi-event seasons

Year	Event ID	Day	LF Num	SS	LF Seg	CP	Max Wind Speed	Landfall Lat	Landfall Long	Radius Max Wind	Forward Speed	Landfall Angle
1	1	280	1	1	7	984	80	28.291	-96.492	12	15	20
3	2	231	1	3	22	963	113	29.472	-83.236	11	14	23
4	3	269	1	2	43	979	96	34.891	-76.420	13	23	32
4	4	230	1	2	5	969	102	27.048	-97.297	12	19	45
5	5	285	1	2	4	975	97	26.002	-97.160	14	18	34
8	6	289	1	4	10	944	132	29.689	-93.713	9	20	18
8	7	204	1	1	39	987	76	32.937	-79.563	16	18	19
8	8	245	1	3	30	957	114	25.952	-80.131	12	16	23
11	9	290	1	2	43	979	98	34.930	-76.330	18	16	20
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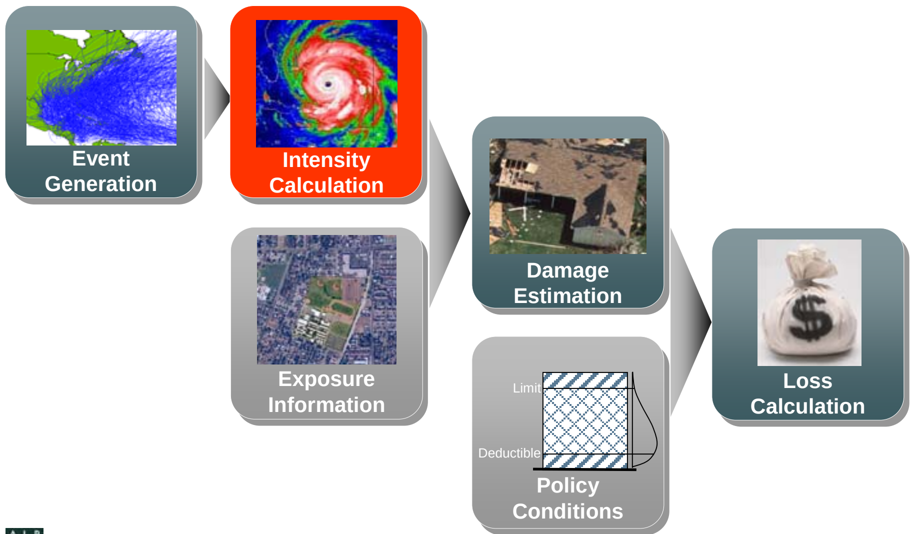
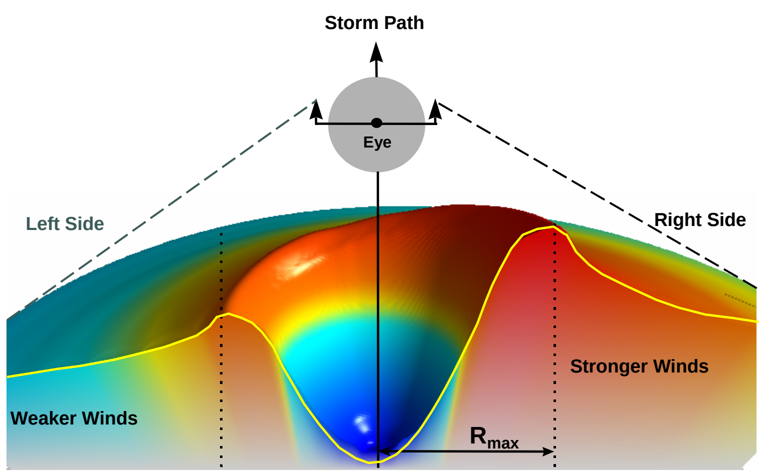
Local Intensity Calculation



Windfield Cross Section

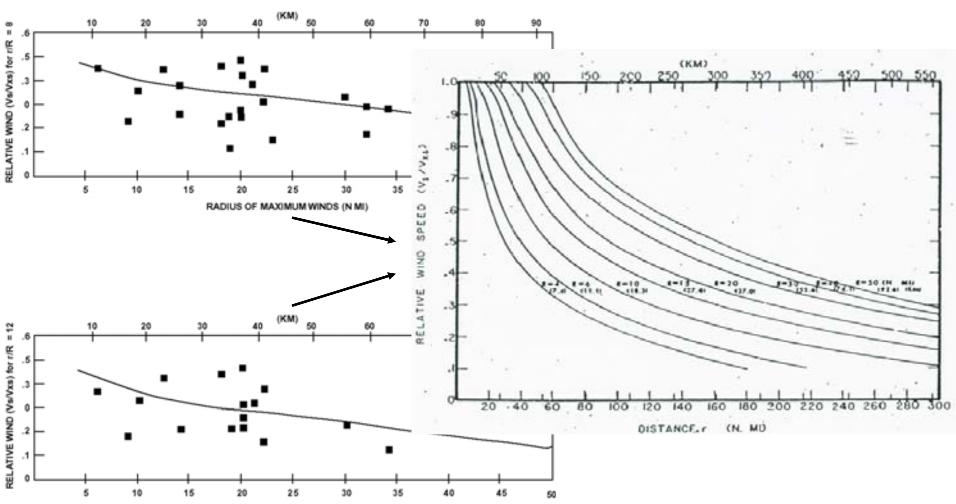


Simulated Windfield Requires Calculations Using Meteorological Variables

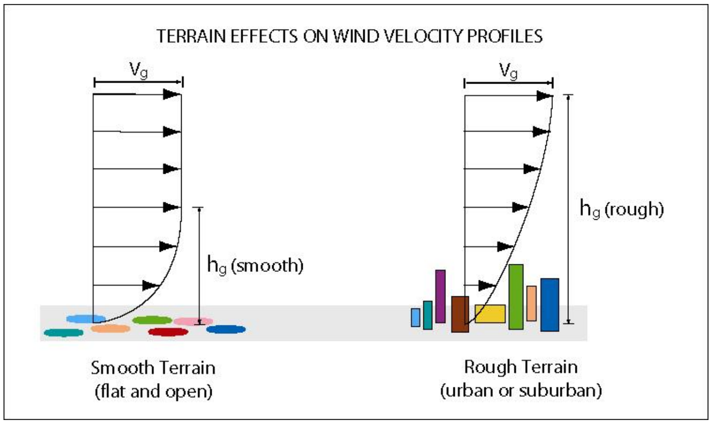
$$V_{1\min,10m}(t, r > R, z_0) =$$
$$(fr(z_0))\left\{ gf(z_0, t_{tav})\left(c_1 e^{-t^{c_2}}\right)\left(c_3\left[\sqrt{\frac{1}{\boxed{\rho} e}(P_w - P_0)} - \frac{\boxed{R}\boxed{f}}{2}\right]\left[c_4 + c_5 \ln(c_6 \boxed{R}) + (c_7 + c_8 \ln(c_6 \boxed{R}))\ln(c_6 r)\right]\right) + 1.5 T^{c_9} T_0^{c_{10}} \cos(\beta) \right\}$$

- Difference between minimum central pressure and peripheral pressure
- Coriolis parameter, dependent on latitude
- Air density coefficient, dependent on latitude
- Radius of maximum winds
- Storm's forward, or translational, speed
- Radial distance from storm center to location
- Angle between track direction and surface wind direction
- Storm inflow angle
- Wind gust factor as a function of surface roughness and averaging time
- Air density factor

Wind Speed Profiles Derived from Historical Data



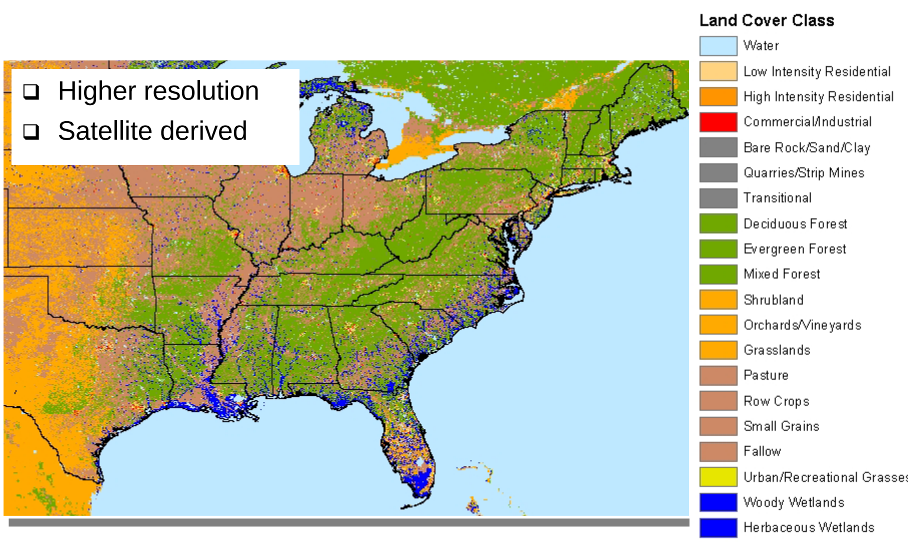
Terrain Effects on Wind Velocity Profiles



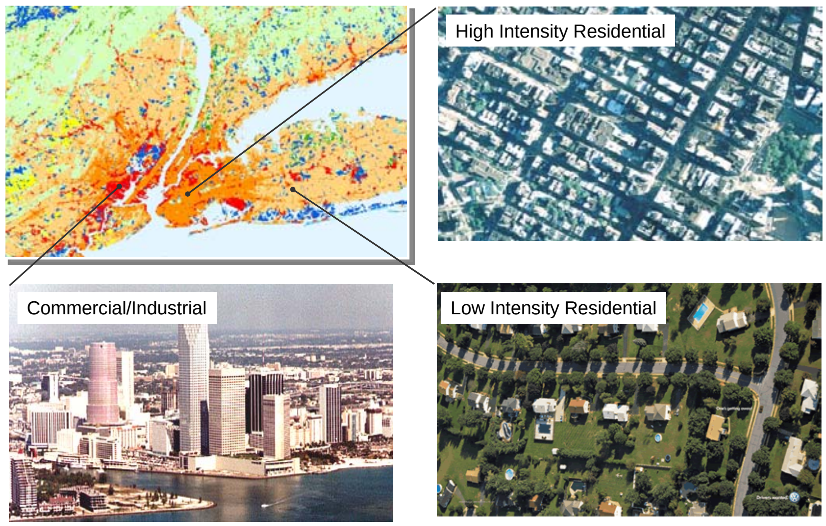
Sources: Simiu and Scanlan “Wind Effects on Structures”, N. Cook “The Designers Guide to Wind Loading of Building Structures. Part 1.”, ESDU Engineering Sciences Data “Wind Engineering.”, etc.

High Resolution Land Use / Land Cover Data

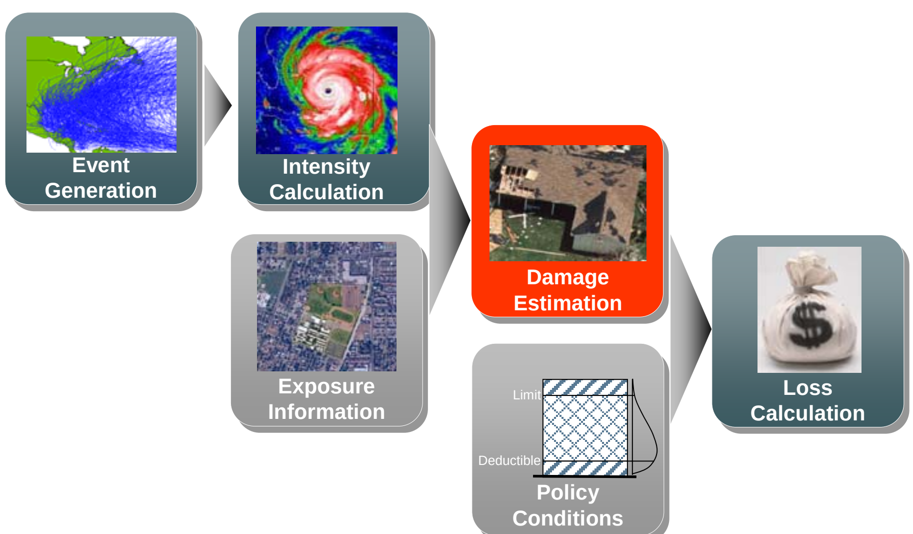
- Higher resolution
- Satellite derived



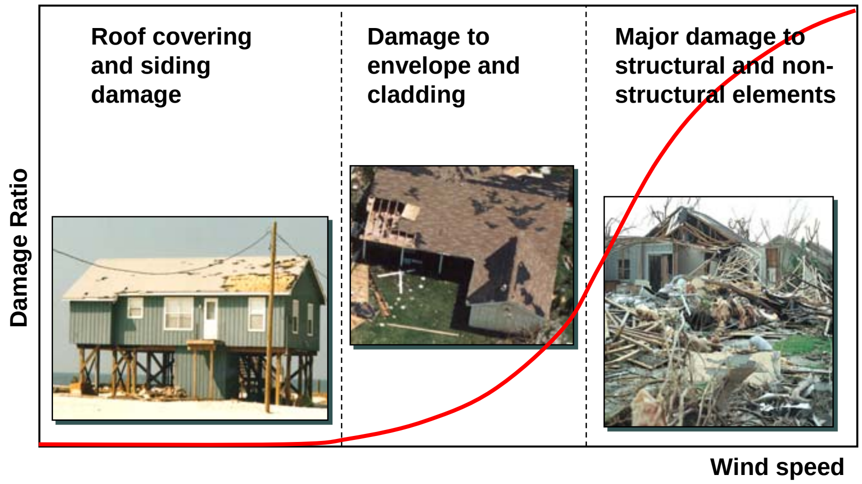
Examples of High Resolution Land Use Data



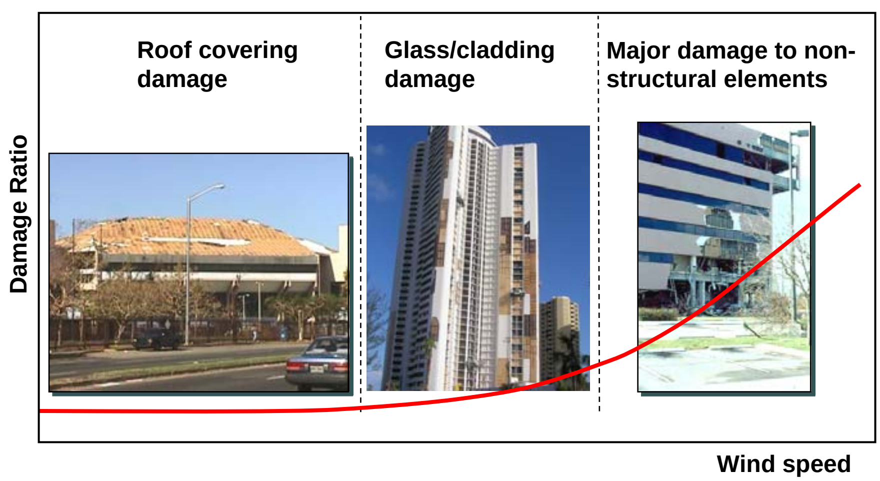
Damage Estimation



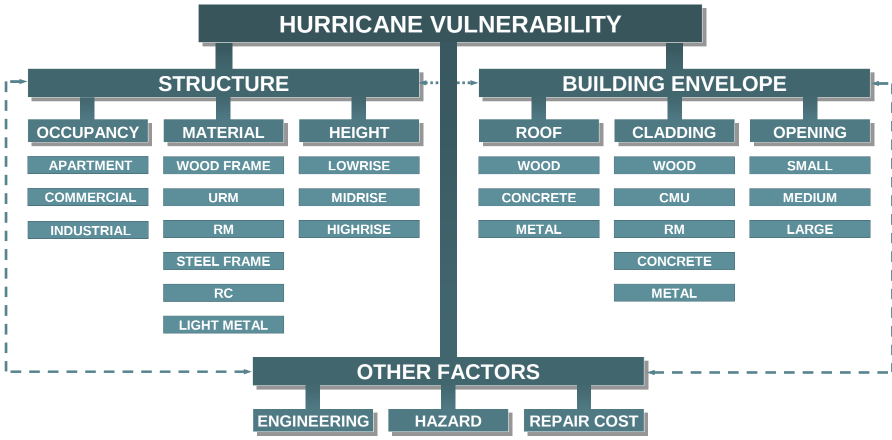
Damage Function - Residential Wood Frame



Damage Function - Reinforced Concrete and Steel Frame



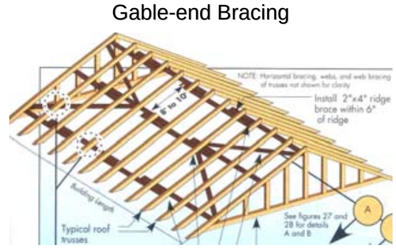
Hurricane Component Vulnerability Model



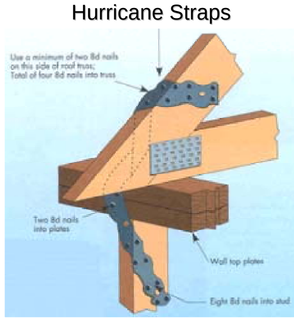
Specific Building Characteristics and Mitigation

110 mph rated Shingles

Gable-end Bracing



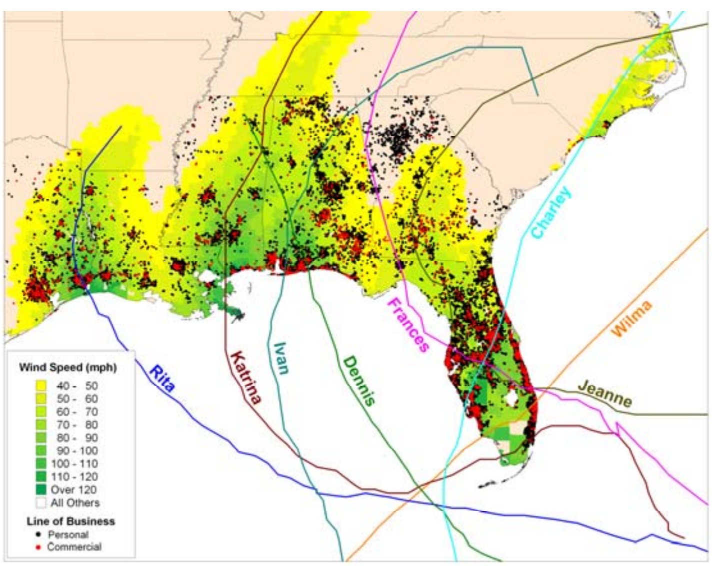
Hurricane Straps



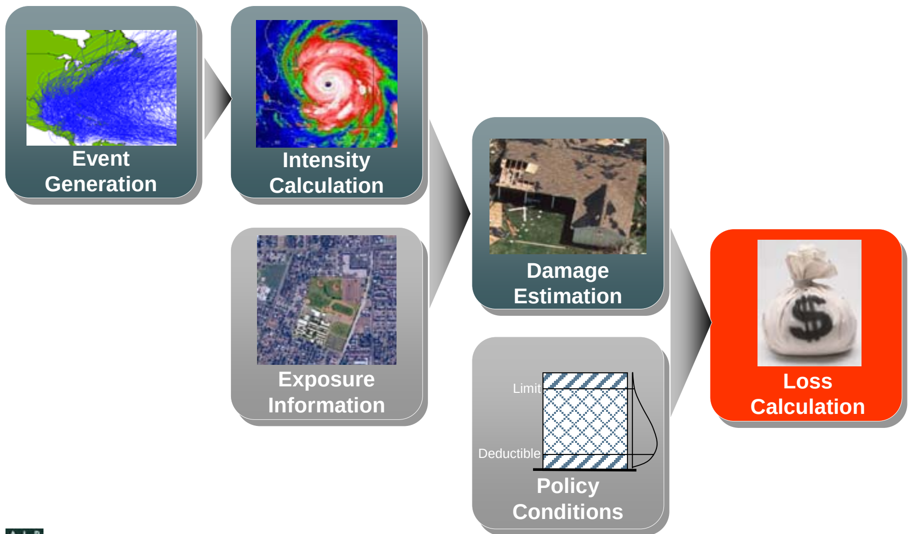
Hurricane Shutters/Impact-Resistant Glazing

Damage Functions Are Validated Through Extensive Post Disaster Surveys

Damage Functions Incorporate Findings from Analysis of Detailed Claims Data



Catastrophe Modeling Framework



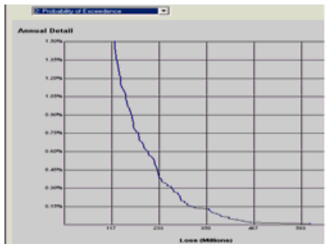
Complex Policy Conditions Captured by the Model

Limits		Deductibles		Reinsurance*	
Location	*Policy*	*Location*	*Policy*	*Location*	*Policy*
Site Limits	Blanket Policy Limits	Combined ($ or %)	Attachment Point	Proportional Facultative	Proportional Facultative
Coverage Specific Limits	Excess Policy Limits	Combined Excluding Time ($ or %)	Blanket	Non-Proportional Facultative	Non-Proportional Facultative
Building	Blanket Policy Sub-Limits	Coverage Specific ($ or %)	Franchise	Surplus-Share	Surplus-Share
Appurtenant Structures	Excess Policy Sub-Limits	Building	Minimum / Maximum		
Contents		Appurtenant Structures	Percent of Loss		
Time Element		Contents			
		Time Element			
		CEA Mini-Policy			

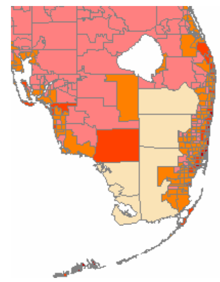
***** *Catastrophe Excess of Loss, Aggregate Excess of Loss, Quota Share, Surplus Share, and Per Risk Treaties are also available for application to the entire portfolio*

Catastrophe Models Provide a Wide Range of Outputs

Loss Exceedance Probabilities

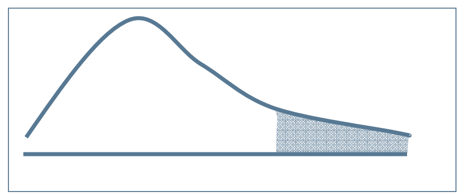


Loss Costs



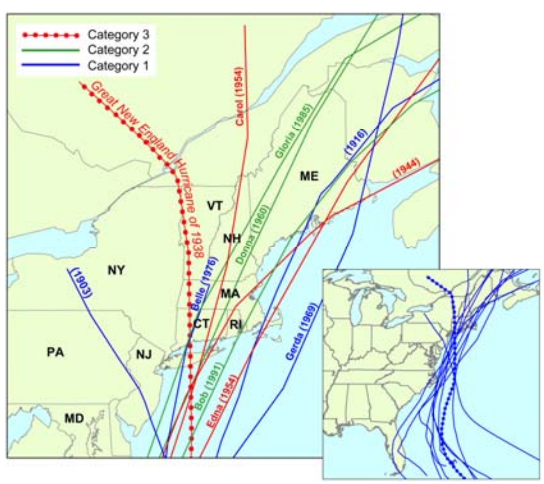
Location Level Loss and Hazard Data

Tail Loss Risk [TVAR]



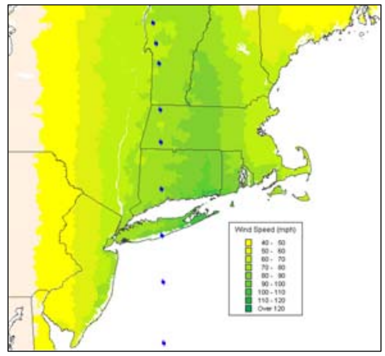
Historical Hurricane Activity in New York and New England

- Since 1900, eleven hurricanes have made a direct hit on New England, six on the New York coastline



The Great New England Hurricane of 1938

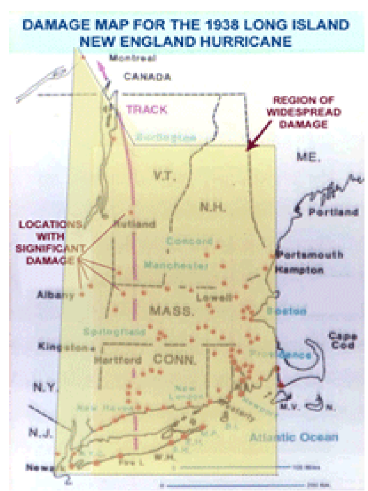
- The Great New England Hurricane was one of the most destructive storms ever to hit the northeast
  - A central pressure of 946 mb, consistent with a very strong Category 3 hurricane, was reported at Bellport, NY
  - Maximum sustained winds of 121 mph were reported at Block Island
  - A peak gust of 186 mph was recorded at the Blue Hill Observatory in Massachusetts
  - Storm surge of 10 - 12 ft inundated the coasts of Long Island, Rhode Island, Connecticut, and southeastern Massachusetts
- The storm was traveling at a forward speed of 50 miles per hour, bringing hurricane force winds far inland



AIR modeled wind speeds for the 1938 storm

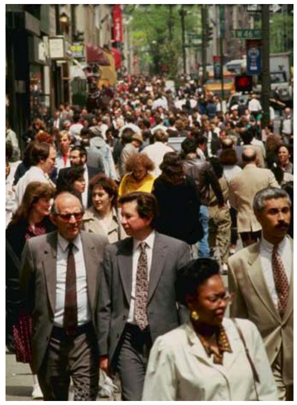
Damage from The Great New England Hurricane

- Significant structural damage occurred as far inland as Worcester, MA
- Approximately two billion trees were destroyed
- Thousands of buildings were destroyed and, in some cases, entire coastal communities disappeared
- The fishing industry was decimated, with about some 5,000 boats damaged or destroyed
- 700 fatalities; 63,000 left homeless



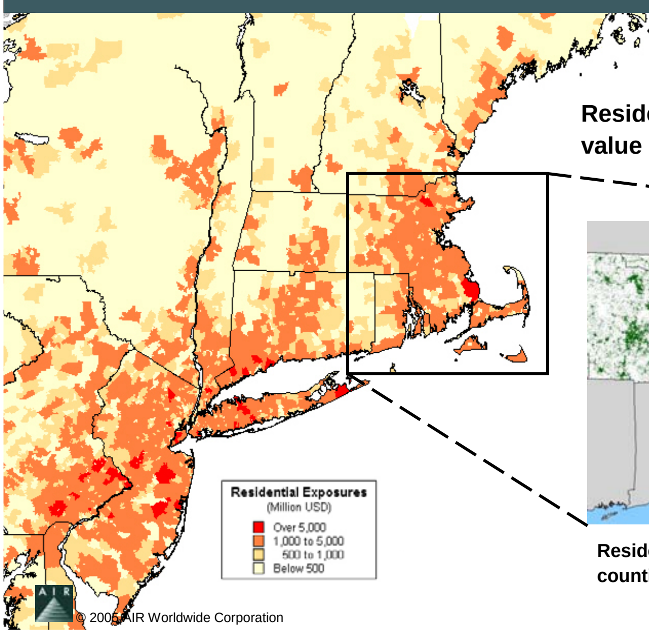
Source: Prof. Nicholas K. Coch

What Has Changed Since 1938

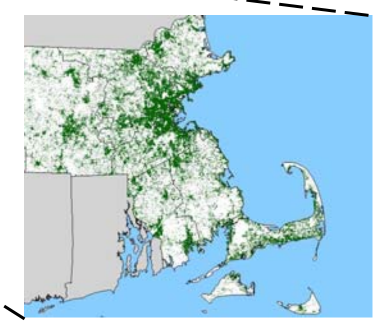


- The number of single family homes has tripled; total value is 13 times higher
- Population has increased by 80%
- Mean sea level has risen by 6 inches

What Is At Risk Today: Exposed Residential Property Values

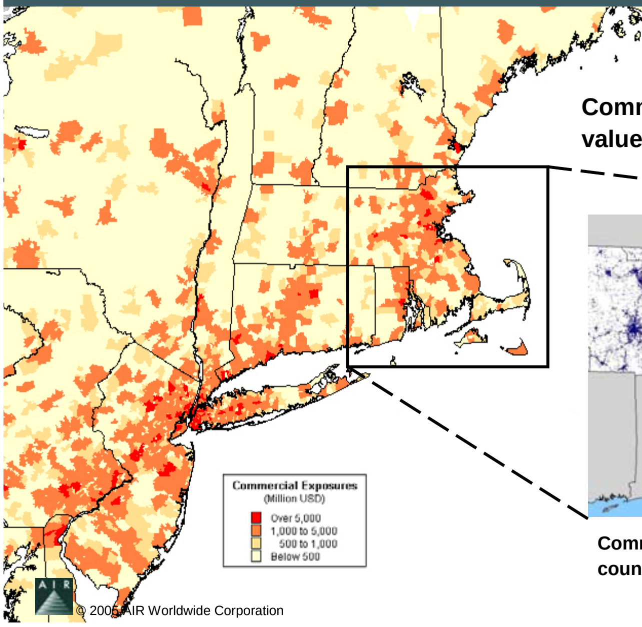


Residential property value at risk ~ $3.4 trillion

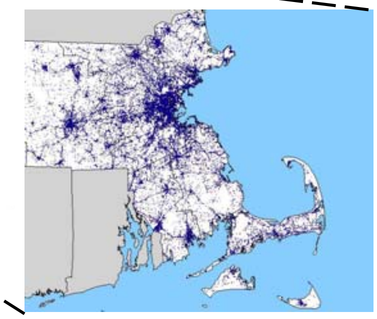


Residential property value in coastal counties of Massachusetts ~ $307B

What Is At Risk Today: Exposed Commercial Property Values

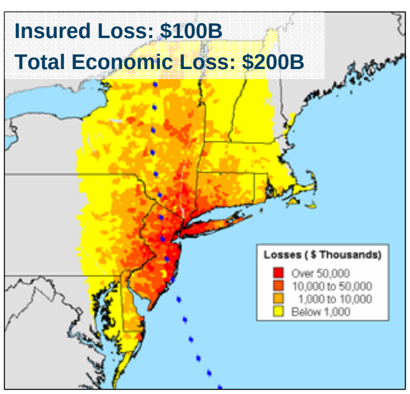


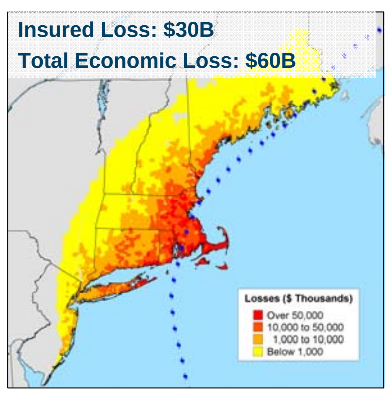
Commercial property value at risk ~ $4.4 trillion



Commercial property value in coastal counties of Massachusetts ~ $356B

How Large Can the Losses Be?

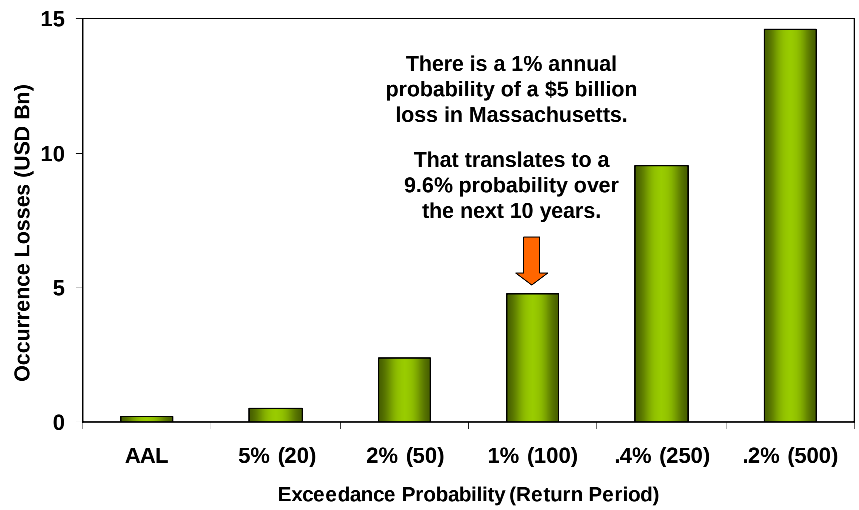




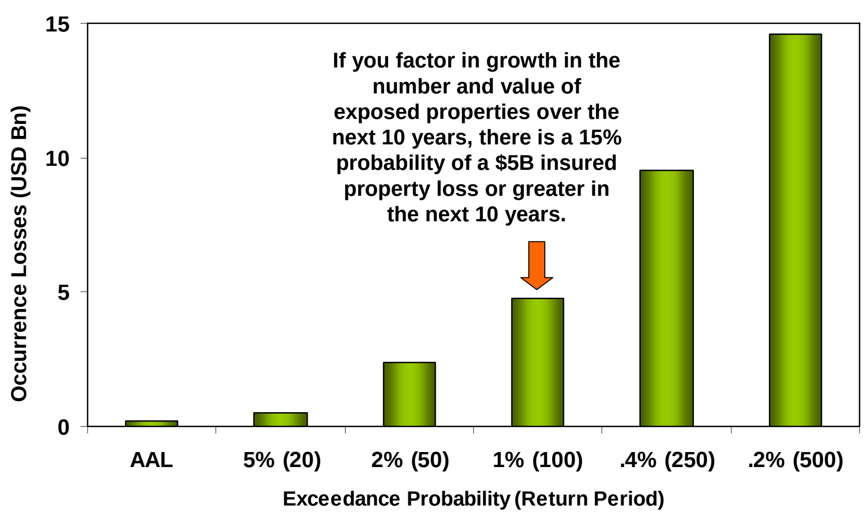
- Even a strong Cat 3 or weak Cat 4 could cause over $100 B in loss in the densely populated Northeast
- Lower Manhattan and Long Island would experience significant damage from flooding to properties and infrastructure

- Category 3/4 hurricane would push water into both Narragansett and Buzzards Bay, causing extensive flooding
- Wind damage and power outages would be widespread

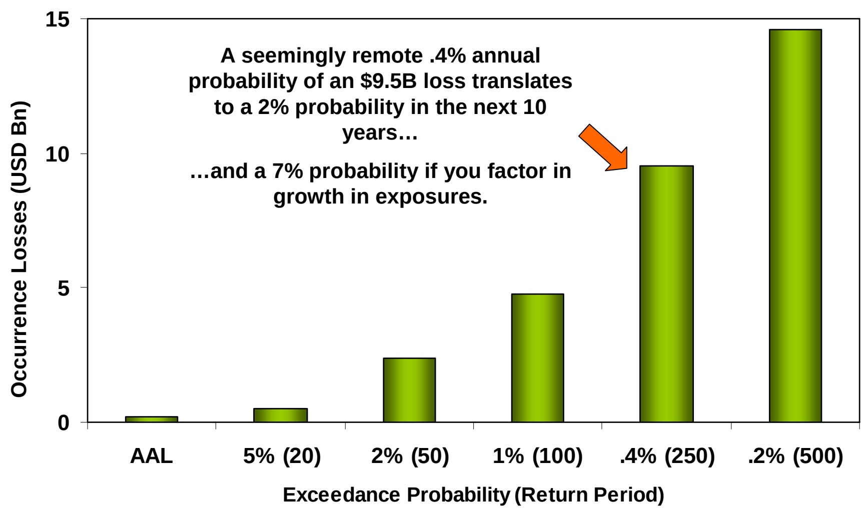
How Large Can the Losses Be in Massachusetts?



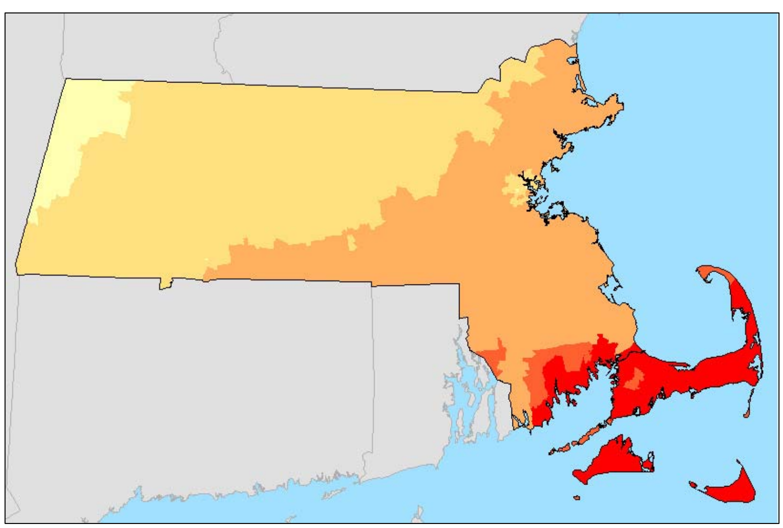
How Large Can the Losses Be in Massachusetts?



How Large Can the Losses Be in Massachusetts?

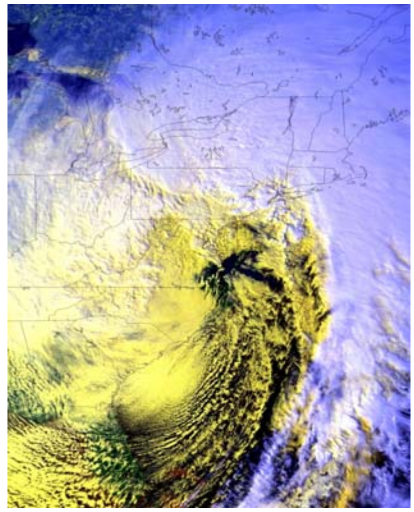


Relative Hurricane Risk for Residential Properties in Massachusetts



Winter Storm Risk

- Blizzard of ’78
- The Storm of the Century (’93)
- Blizzard of ‘97
- Blizzard of 2003



Summary

- While the frequency is low, New England and Massachusetts are exposed to major losses from hurricanes and winter storms
- The risk is increasing—driven primarily by the increase in the number and value of exposed properties
- There is a 15% probability that Massachusetts will experience a $5 billion insured loss, or greater, in the next 10 years